Turbulence Modeling Validation Study

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The present study is part of an ongoing effort to evaluate and develop turbulence models for aerodynamic applications. The objective of the study was to investigate the performance of several turbulence models on a variety of aerodynamic flows and to make recommendations regarding their applicability in aeronautical applications. The models studied were the Jones-Launder k-ε model, the k-ω model of Wilcox, the one-equation model of Spalart and Allmaras, and the two-equation k-ω shear-stress transport (SST) model of Menter. Ten flows were investigated including five free-shear flows and five boundary-layer flows, of which three were complex flows involving separation or shock waves or both. The results of numerical predictions were compared with experimental results, which included surface pressures, skin friction, and profiles of velocity and turbulent kinetic energy and shear stress.

The turbulence models were evaluated on the basis of numerical accuracy with respect to experimental results, numerical sensitivity to grid spacing and refinement, sensitivity to free-stream turbulence conditions, and the choice of the numerical code. Typical results of the study are shown in the figures.

Model Performance

Model	k-ω	k-ε	S-A	SST
Mixing layer	□	■	■	■
Far wake	□	○	■	○
Plane jet	□	■	○	■
Round jet	□	●	□	●
ZPG BL	■	■	■	■
APG BL	○	□	●	■
Trans. bump	○	□	▲	●
RAE 2822	○	□	▲	●

Scale: (Bad) □ ○ ▲ ● ■ (Good)

Fig. 1. Numerical grid and surface pressure distributions for the RAE 2822 transonic airfoil (case 10).

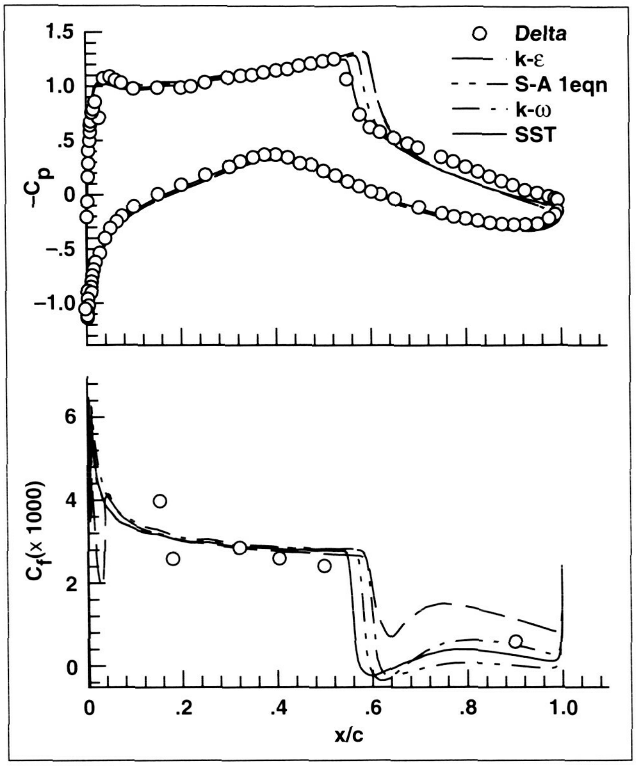

Fig. 2. Numerical performance and sensitivity ratings of turbulence models.

The first figure shows the results for a transonic airfoil flow and indicates the numerical grid used and the measured and computed pressures and skin friction on the surface of the airfoil. Results comparing the performance of the four models for eight of the flows studied and the model sensitivity to various conditions are shown in the second figure. From these results it was found that the Menter SST model gave the best overall results followed by the Spalart-Allmaras model and then the k-ω and k-ε models. With respect to sensitivity, the Spalart-Allmaras model gave the best results, closely followed by the SST model and then the k-ω and k-ε models.

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